

Disentangling the sources of Single Spin Asymmetries

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1. Sources of SSA = sources of imaginary phases .
2. Collins vs Sivers; in-jet vs jet asymmetry
3. Collins vs Sivers: how generic is the suppression.
4. RHIC vs E704 - gluonic and fermionic poles
5. Conclusions

SSA - requires imaginary part - due to generalized optical theorem - cut in SOME variable

QCD factorization:

FSI - cuts in jet mass - Collins function

ISI and FSI - cuts in s - twist-3 : fermionic (soft fermion) or gluonic (soft gluon) poles

Some gluonic poles (gluonic exponential) - Sivers function (effective, non-universal) - no variable like the jet mass for initial particle)

Correlated distribution and fragmentation - cuts in s_1 (T-odd) fracture function - may help to resolve the signals for the violation of factorization for transverse SSA at HERMES, discussed at A. Efremov talk.

T-even spin-dependent fracture functions - talk of A. Kotzinian

How to disentangle all this mess?

No complete solution - some hints

(3 for 15 min)

Request for experimentalists

Collins and Sivers do lead to DIFFERENT observables IF hadron in a JET is detected

Sivers - azimuthal ($\sin\phi$) asymmetry of the jet itself

Collins - azimuthal asymmetry of the hadron INSIDE the jet

Averaging of the jet directions - the same observable

Is it possible not to average?

Are the jets directions non-symmetric

Are the jets shaped?

For integration over jets direction - Collins and Sivers contribute together BUT

Recent observation of Cagliari-London-Torino group (talk of U. d'Alesio) -suppression of Collins with respect to Sivers

How generic is it?

(2-nd) Mean value theorem

$$A_h = \frac{\int d\vec{x} \Delta\sigma(\vec{x})}{\int d\vec{x} \sigma(\vec{x})} = \frac{\Delta\sigma(\vec{x}_0)}{\sigma(\vec{x}_0)} = A_p(x_0) \quad (1)$$

Here \vec{x} includes all transverse momentum and/or momentum fractions, Hadronic asymmetry is equal to partonic one at SOME point x_0 which compromises between maxima of σ and A . Usually they correspond to different regions -suppression of hadronic asymmetry with respect to partonic one EXCEPT $\Delta\sigma$ and σ are similar.

Sivers function case

$$A_h = \frac{\int d\vec{x} [f_T D \hat{\sigma}](\vec{x})}{\int d\vec{x} [f D \hat{\sigma}](\vec{x})} = \frac{f_T(\vec{x}_0)}{f(\vec{x}_0)} \quad (2)$$

In the case Sivers function is modelled similarly to unpolarized one - no reasons for suppression. BUT! maybe quite different because of its effective nature

Compare with Collins function

$$A_h = \frac{\int d\vec{x} [\delta f H \delta \hat{\sigma}](\vec{x})}{\int d\vec{x} [f D \hat{\sigma}](\vec{x})} = \frac{[\delta f H \delta \hat{\sigma}](\vec{x}_0)}{[f D \hat{\sigma}](\vec{x}_0)} \quad (3)$$

Extra generic suppression due to partonic analyzing power!

Complication due to many quark flavours - purities

$$A_h = \frac{\sum_i \int d\vec{x} \Delta\sigma_i(\vec{x})}{\sum_i \int d\vec{x} \sigma_i(\vec{x})} = \sum_i P_i(\vec{x}_0) \frac{\Delta\sigma_i(\vec{x}_0)}{\sigma_i(\vec{x}_0)} = \sum_i P_i(\vec{x}_0) A_p^i(x_0)$$

$$P_i(\vec{x}_0) = \frac{\sigma_i(\vec{x}_0)}{\sum_k \sigma_k(\vec{x}_0)}; \quad \sum_i P_i = 1 \quad (4)$$

For Sivers - purities involve dependence also on fragmentation functions and partonic cross-sections, but not significant unless for some accidental reason large asymmetry is accompanied by small purity

Imaginary phase (T-odd effects in T-conserving theories) - loops including large and soft distances - genuine twist 3

Soft quarks - fermionic poles (A.V. Efremov, O.T. (85,95)) (DY - no suppression as $1/Q$, still behaves like M/p_T). But consideration of small $P_T \sim M$ - illegitimate - all twists are important.

Soft gluons - gluonic poles - considered to be dominant for large x_F (easier to emit soft gluon than soft quark) - detailed numerics exists (J.Qiu, G. Sterman (91,98))

However

Gluonic poles predictions for large x_F - go above RHIC data.

Gluonic poles - related to genuine twist contribution to $\int dx x^2 g_2$ - small.

Fermionic poles should be reanalyzed.

Another argument - from unpolarized cross-sections
NLO - much better description of RHIC than E704 kinematics
(C. Bourrely, J. Soffer (78)) Why (no explicit energy dependence in QCD) ? Possible origin - HT - the typical partonic $x_i \sim p_T/\sqrt{s}$ - larger for E704. HT typically grow with x - less important for RHIC.

Gluonic poles: $\Delta\sigma \sim 1/(1-x)$ - to preserve positivity requires the growing with x spin independent HT term. If it is small, gluonic poles also cannot be large.

1. Experimental detection of jet asymmetry and in-jet asymmetry of hadrons - BEST way to disentangle Collins and Twist-3/Sivers
2. Non-suppression of Sivers - generic unless Sivers functions is very different from unpolarized one; suppression of Collins - generic.
3. Different situation with unpolarized NLO at E704 and RHIC - may be a signal for disentangling fermionic and gluonic poles.